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Review

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Anterior Cruciate Ligament Reconstruction: Which Graft to Use?

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Abstract

The anterior cruciate ligament is the most commonly injured ligament within the knee and its injury mostly occurs among young and active individuals. In the last few decades, the proper kind of graft choice that should be used for cruciate ligament reconstruction has been controversial. In addition to bone-patellar and tendon-bone autografts, many other choices have become popular, such as using hamstring tendons and allografts. The aim of this article is to evaluate the kinds of choices that are available for grafting and to assess their advantages, disadvantages, clinical outcome, donor site morbidity, and biomechanical criteria and healing factors. In conclusion, there are certain situations where one graft may be favored over another. However, a universally accepted ideal graft choice currently does not exist. Therefore, a good surgeon should be familiar with the different types of grafting choices.

Keywords: Anterior cruciate ligament; Reconstruction; Graft choice; Autograft; Allograft

Introduction

A rupture of the anterior cruciate ligament (ACL) is the most common when it comes to knee injuries [1]. The stability of the knee is greatly reduced by an anterior cruciate ligament rupture. The symptoms resulting from this further increase the risk of meniscus related injuries and an early degeneration of the injured knee mostly due to sports activities [2].

A rupture of the ACL requires surgical intervention in majority of cases and ACL reconstruction aims to restore stability to the knee [3]. Recent advances in the understanding of the biomechanical and biological properties of an intact ACL, have created numerous surgical reconstruction techniques to the point where various graft choices have evolved [3]. However, the most ideal graft tissue for ACL reconstruction has been the subject of on-going debate [4].

The kind of choice is based on many different factors. The graft must be easily accessible, result in fewer donor site morbidity, and allow for immediate rigid fixation and undergo rapid healing. Ultimately, the mechanical properties of the graft must reproduce those of the native ACL in order to restore function and permit a return to pre-injury activities [5].

The aim of this article is to evaluate the kinds of grafting choices that are available which, includes their advantages and disadvantages, their clinical outcomes, morbidity on the donor side, and their biomechanical characteristics and healing potentials.

Anatomy and Biomechanics of the ACL

The ACL is a complex ligament that originates on the posterior-medial aspect of the intercondylar notch. In this position, the ACL acts as a primary restraint of the anterior translation of the tibia on the femur [6]. Additionally, the ACL has important proprioceptive properties. It contains different sets of mechanoreceptors that provide the central nervous system with afferent information about the position of the joint [7].

The ACL is approximately 30 mm long and 10 mm wide. It consists of two bundles, anteromedial (AM) and posterolateral (PL), which display different characteristics. When the knee is extended, the PL bundle is tightened and then the AM bundle is lax. As the knee is flexed, the AM bundle is tightened and the PL bundle is lax. Consequently, the PL bundle plays an important role when the knee is near its full extension [7].

The ultimate tensile strength of the ACL has been measured from 1725 N to 2195 N. The stiffness of the ACL

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has been determined from cadaver knees and is reported as varying from 242 N/mm to 306 N/mm. The ACL changes approximately 2.5 mm in length when the knee is moved through its normal arc of motion and a selected graft should have similar characteristics [8, 9].

Choice for Grafting

Autografts

An autograft tissue is the most common type of graft used in ACL reconstruction. Autograft choices are central third bone-patellar tendon bones (BPTBs), semitendonosus and gracilis hamstring tendons, and central third quadriceps tendons [10].

Using the BPTB graft for ACL reconstruction has been a standard procedure in recent decades and is sometimes referred to as the gold standard [10]. Nonetheless, the graft is criticized for resulting in a significant harvest resulting in site morbidity that includes complications such as anterior knee pain when kneeling, patellar fracture, patellofemoral crepitation and possible loss of quadricep strength [11].

Therefore, the popularity for using a hamstring tendon as an autograft for ACL reconstruction has recently increased [11]. The hamstring tendon graft is typically used for semitendinosus and gracilis tendons or for semitendinosus alone. Interestingly, a recent hypothesis asserts that semitendinosus and gracilis tendons regenerate after harvest. This hypothesis has been supported by Ferretti et al who visualized through surgery fibrous bands reproducing pathways through the native semitendinosus tendon. These findings were further reinforced through a histological examination showing spindle shaped cells that closely resemble tenocytes [12]. However, the hamstring tendon autograft has been criticized for its lack of strength and stiffness of the graft [11].

A quadriceps tendon graft is less common albeit a viable graft option for a primary and perhaps more commonly used revision of ACL reconstructive surgery. It provides a large tendonous graft with a bone plug on one end of the graft. Nonetheless, the tendon graft harvest also has the potential morbidity of disrupting the extensor mechanism [13, 14].

Biomechanical Comparison

Simonian et al evaluated the effect of sub-maximal cyclical loads on the tendinous portion of a 10 mm wide section from the third central patellar tendon and from double semitendinosus and gracilis tendons obtained from six fresh frozen cadavers. They found that there is no significant difference in the strain, stress or modulus between the two types of grafts [15].

Wilson et al conducted biomechanical testing of 15 matched pairs of central-third bone-patellar tendon-bone and double-looped semitendinosus-gracilis grafts harvested from 15 cadaver knees. There were not any statistically significant differences in stiffness between the grafts. However, the hamstring tendon grafts were significantly stronger than the matched central-third patellar tendon grafts. The patellar tendon grafts also had a higher modulus than the hamstring tendon grafts [16].

Staubli et al analyzed the mechanical tensile properties of 16 full-thickness central parts of quadricep tendons and patellar ligaments from paired knees of eight male donors. The mean cross-sectional area of the quadriceps tendons was significantly larger than that of the patellar tendons. Nevertheless, the mean ultimate values for tensile stress of the patellar tendons were significantly larger than those of the quadricep tendons [17].

Functional Outcomes

The strength and stiffness of the grafts are important components, but functional outcomes are what to determine the success or failure of surgical interventions [18]. Shaieb et al reported a prospective randomized study comparing the BPTB versus a semitendinosus and gracilis tendon autograft. In this study, 70 patients were monitored for up to 2 years and interference screws were used to affix both types of grafts. The only statistically significant findings included less range of motion and more patellofemoral pain with the BPTB autograft [19].

In an Ejerhed et al study, 71 patients who had a unilateral anterior cruciate ligament rupture underwent arthroscopic reconstruction with interference screw fixation and with the use of either a bone-patellar tendon-bone or semitendinosus tendon graft. By the end of year two, no differences were found in terms of the Lysholm score, the Tegner activity level, KT-1000 arthrometer side-to-side laxity measurement or in a single-legged hop test. The only significant difference was that the patients with a semitendinosus graft had a statistically better ability to walk on their knees [20].

Beard et al conducted a randomized controlled trial where 60 patients randomly received either a BPTB autograft or a 4-strand semitendinousis gracilis autograft. The functional scores, activity level, muscle strength and anterior tibial translation improved in both groups. Significant differences between groups were not found for any measurement at 6 months and at 1 year. The study indicated that the year 1 results for either technique were equally favorable [21].

Similarly, in Eriksson et al study, 164 patients with a unilateral instability of the anterior cruciate ligament were randomly chosen to undergo arthroscopic reconstruction with either a patellar tendon graft using interference screw fixation or a quadruple semitendinosus graft using an endobutton fixation technique. All patients underwent the same

postoperative rehabilitation protocol and follow-up over the course of approximately 31 months. Significant differences were not found between any of the groups regarding the Stryker laxity test, one-leg hop test, Tegner activity level, Lysholm score, patellofemoral pain score, International Knee Documentation Committee (IKDC) score or visual analogue scale. It was concluded that the patellar tendon and quadruple semitendinous tendon grafts have similar outcomes on a medium length time-scale [22].

Nonetheless, in the literature, there are two meta-analysis studies comparing the results after ACL reconstruction using BPTB or hamstring tendon autografts. Both studies revealed less laxity in the BPTB group [4, 23].

There have not been enough articles in the literature that have assessed the results of quadricep tendon autografts or by comparing it with other types of autografts. However, Lee et al [24] reported a study aiming at determining the outcome of ACL reconstruction using a quadriceps tendon autograft. Sixty-seven ACL reconstructions were evaluated over an average of 41 months. Clinical assessments were made using a modified Lysholm score, documentation of IKDC, the anterior knee pain questionnaire of Shelbourne and Trumper, and through KT-2000 arthrometric analysis. Arthrometric analysis showed that 63 knees (94%) were graded A or B with a median laxity of 2 mm postoperatively. The Lysholm score improved postoperatively from 71 to 90. The study concluded that a quadriceps tendon can be a reliable source for a graft.

Additionally, Geib et al [25] compared the intermediate term outcome results of an ACL reconstruction through the use of a BPTB and quadriceps tendon (QT) with and without a bone block. When compared to BPTB autograft, the quadriceps tendon autograft showed significantly better results, including: less anterior knee pain, less anterior numbness, a higher percentage of arthrometer measurements showing a side-to-side difference of 0-3 mm and better extension. There also was not any significant difference between the 2 groups in the loss of flexion. According to the Lachman test and the pivot-shift test, there was not a presence of effusion or indications of any other failures.

Donor Site Morbidity

Donor site morbidity represents a distinct disadvantage when using an autograft for an ACL injury. However there is less morbidity associated with the harvesting of a hamstring tendon. This could be attributed to the fact that the semitendinosus grows back in a reliable way [26, 27].

Anterior knee pain

Anterior knee pain is common after ACL reconstruction, the symptoms can occur anywhere along the extensor mechanism [28]. Anterior knee pain following BPTB is a significant problem. Pinczewski et al [29] and Freedman et al [4] reported that the incidence of anterior knee pain was significantly higher with a BPTB graft than with a hamstring graft. Nevertheless, Ejerhed et al [20] suggested that little difference exists in the incidence of anterior knee pain between BPTB and hamstring grafts.

Geib et al [25] and Han et al [30] found the incidence of anterior knee pain to be significantly lower with a quadriceps tendon autograft than with a BPTB. On the contrary, Lee et al [24] reported that an incidence of anterior knee pain was similar for quadriceps tendons and hamstring tendon autografts.

Kneeling pain is defined as pain produced through the application of direct pressure on the patellar tendon and is detected by having the patient walk on their knee. Kneeling pain has received a significant amount of attention in the literature [31]. Ejerhed et al [20] stressed the importance of kneeling and knee walking for many individuals undergoing ACL reconstruction. This is particularly important in patients who work in construction where kneeling is an integral part of their job, in child care and in religious ceremonies. Goldblatt et al [5] and Spindler et al [32] reported that kneeling pain increased significantly in patients with BPTB compared to those with hamstring grafts. Kim et al [33] reported kneeling pain in 13 of 27 patients following a BPTB graft compared to 4 out of 21 patients who were treated with a quadriceps graft.

Donor Site Weakness

There is a demonstrable loss of power in the associated muscles after a repair of the ACL. The quadriceps muscle is substantially weakened after a harvest of BPTB and quadriceps tendon grafts. Lee et al [34] reported a strength reduction of 20% after year 1 and 15% 3 years later. However, in order to determine whether this quadriceps deficit is due to knee injury itself or to the process that was used to harvest of the graft, the strength of the quadriceps has been compared to a reconstruction of the patellar tendon by autograft and by allograft. Surprisingly, Stringhan et al [35] have shown a relative weakness in the quadriceps without any noticeable difference between the autograft and allograft.

Some studies have compared muscle strength with a patellar tendon or hamstring graft. Interestingly, Carter and Edinger [36] evaluated 106 patients at 6 months and did not show any statistically significant difference in the strength of an isokinetic flexion and extension between both grafts.

Numbness of the Anterior Knee

It is caused by injury to the infrapatellar branch of the saphe-

nous nerve during a graft harvest. Injury to the nerve may occur with an arthroscopic portal placement or an incision may be made in order to harvest BPTB grafts. The incidence of anterior knee numbness is dramatically higher with a BPTB graft in comparison to a hamstring and quadriceps harvest [31]. Geib et al [25] reported symptomatic anterior numbness in 35% of the following BPTB harvest compared to 1.5% following quadriceps tendon harvest.

Fracture of the Patella

Patellar fractures have been reported with a BPTB and quadriceps tendon graft with a bone plug. Christen and Jackob [37] reported six longitudinal fractures of the patella at the time of the harvest. Moreover, Fulkerson et al recommended the use of a free quadriceps tendon graft in order to reduce morbidity [38]. Nonetheless, it is recommended that when a BPTB or quadriceps tendon graft is used with a bone plug, the patellar defect should be grafted with a bone from a tunnel reaming [31].

Allograft

The absence of morbidity at the donor site, the small incisions required for implantation and less surgical time has led to consideration of the use of allograft in reconstructive ACL surgery [39]. Several studies have compared the results of allografts with autografts in the reconstruction of an ACL. Noyes and Barber-Westin assessed the outcomes of patellar tendon allografts and autografts used for the revision of ACL surgery in 65 patients [40]. There was a notable improvement in the patients' symptoms, function anteroposterior displacement and overall ratings. The failure rates were only 33% for the allografts and 27% for the autografts [40].

Shelton et al [41] compared two groups of 30 patients that received autografts and allografts for over a two year period. There was not a significant difference between the two groups by the end of a 2 years period that was determined to be satisfactory. Additionally, there was not a difference in the formation of patellofermoral crepitus or thigh circumference.

More recently, Peterson et al [42] compared the long-term results of an allograft versus autograft BPTB for ACL reconstruction where 2 groups of 30 patients were evaluated subjectively and objectively with an average follow-up of 63 months. The results showed that there was not any noticeable difference in their graft integrity or a presence of overall morbidity.

It should be noted that a serious potential problem with the use of allografts is a chance that diseases can be transmitted among patients. For instance, a patient died of Clostrdium Sordellii septic shock in 2002 after receiving an infected allograft 2 days earlier [28].

However, the risk of infection has mostly been eliminated due to the development of better donor screening and testing procedures. A detailed medical, social and sexual history must first be obtained for each potential cadaveric donor. Extensive testing includes blood cultures, harvested tissue cultures, and screening for antibodies that might indicated the presence of human immunodeficiency viruses HIV-1 and HIV-2, hepatitis B surface antigen, hepatitis C, syphilis and/or a human T-cell lymphotropic virus [43].

In addition to this kind of extensive screening, an allograft can be sterilized. However, ethylene oxide treatment is no longer used for sterilization because of associated synovitis and intra-articular graft destruction [11]. Gamma irradiation is the most common method of sterilization and is thought to create free radicals and modify nucleic acids causing viral and bacterial destruction. Nevertheless, it had been discovered that more than 2 Mrads of radiation could affect the structural integrity of the ligament, which represents a dose that is not sufficient enough to destroy HIV [44].

Additional drawbacks for the use of allografts include an additional higher cost of the surgical procedure, an immunogenic response of the host to the graft, and delayed graft incorporation in comparison to autografts [11]. Malinin et al [45] studied the rate and the extent of cellular replacement and remodeling of retrieved allografts. Nine specimens of ACL replacement allografts were obtained through various autopsy and surgical procedures. An examination of all of the allografts showed that at 2 years after transplantation, the central portions of the grafts remained acellular with an absence of a complete attachment. However, there was cellular invasion in 3.5-year post-transplantation specimens.

Despite the condition of not having any morbidity from the harvest of the graft, satisfactory properties and ready availability, the allograft is mostly used for revision surgery or when multiple grafts are required when complex instabilities are present [39]. Screening techniques are currently the most predominant ways by which disease transmission can be stopped when applying allografts. [11].

Summary

Patellar tendon autografts may have some advantageous applications for high-demand patients who participate in sports that have a high risk of stressing or injuring joints and desire a quick return to play. However, pre-existing anterior knee pain or certain lifestyles that require a lot of kneeling are relative contraindications to the patellar tendon autografts. Quadriceps tendon autografts are less commonly used but have been reported to have good results. Hamstring grafts are increasing in popularity because of improved fixation techniques, reduced harvest morbidity, and excellent outcome and patient satisfaction scores. Allografts have had a

recent revival. However, the benefits of allografts must be weighed against their higher cost and slower period of incorporation.

Overall, after reviewing the literature, it would seem that a perfect graft for ACL reconstruction does not currently exist. None of the studies to date have been able to indicate a clear advantage when it comes to all of the measured outcomes. Rather than make a generalization about the efficacy of a particular graft, so the modern surgeon should be able to use more than one type and should choose the graft which is the most suitable for any given patient [46].

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